



ARNOLD LIGHTWEIGHT MIRROR MODELER

VERSION 2.0

**WILLIAM R. ARNOLD, SR
DEFENSE ACQUISITION, INC
(SUBCONTRACT WITH JACOBS ESTS)
HUNTSVILLE, ALABAMA**

**H. PHILIP STAHL
NASA MSFC, HUNTSVILLE, AL.**

NASA TECH DAYS 2012

1



HERITAGE



- **SECOND GENERATION OF EGGCRATE MODELER DEVELOPED AT L3-COMM BRASHEAR, PITTSBURGH, PA. USED TO DESIGN PRIMARY MIRROR, SUPPORT SYSTEM AND MIRROR HANDLING EQUIPMENT FOR THE KEPLER PLANET FINDER.**
- **COMPLETE REWRITE FOR USE ON WINDOWS 7 AND ABOVE OPERATING SYSTEMS.**
- **EXPANDED TO MULTI-SEGMENT MIRROR AS WELL AS SINGLE MIRROR SYSTEMS.**

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2



INTEGRATED PRODUCT DESIGN



communications
Brashear



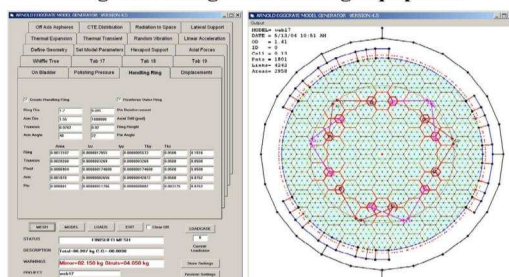
CORNING

JDS Uniphase
OCU Products



Ball Aerospace
& Technologies Corp.

Integrated Design of Handling Equipment



Design tool allows evaluation and design of handling fixtures during the preliminary design of the mirror blank. As mirrors become lighter, the difficulties of handling the glass during manufacturing requires careful attention to these operations. Special reinforced features were added to the blank specifically to aid the manufacturing process and reduce risk.



NASA Tech Days 2004

17



CONVERT ANALYSIS TO DESIGN



communications
Brashear



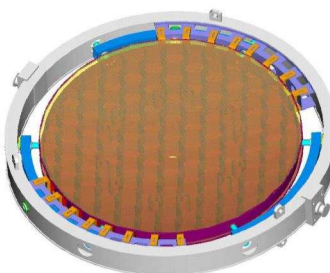
CORNING

JDS Uniphase
OCU Products



Ball Aerospace
& Technologies Corp.

Primary Mirror in Flipping Ring



The handling ring interfaces with special reinforced slots in the mirror core. With the addition of storage shields, the unit can act as a temporary container. Does not touch optical surfaces or fragile edges.

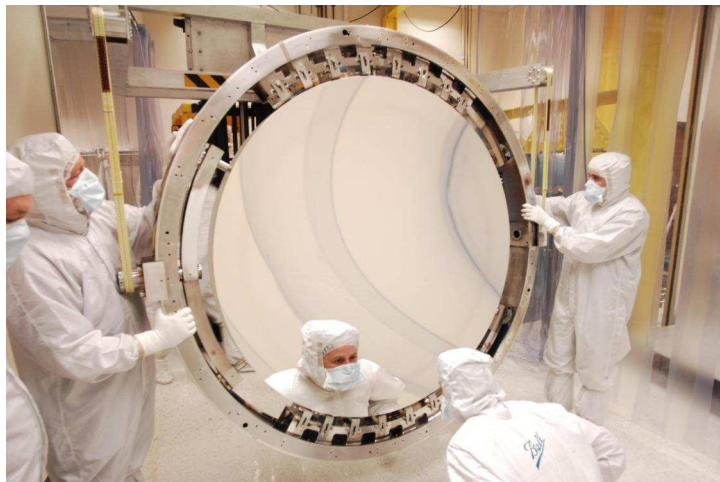


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18



THE FINAL PRODUCT



PROGRAM CONTROL WINDOW

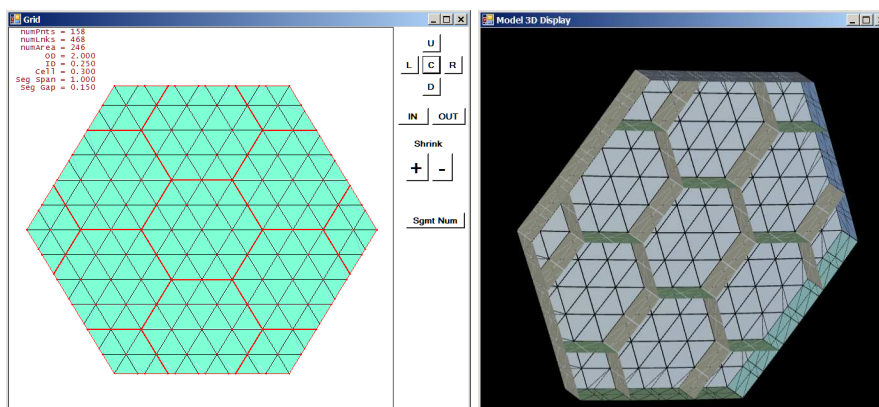


Arnold Lightweight Mirror Modeler (Ver 2.0)

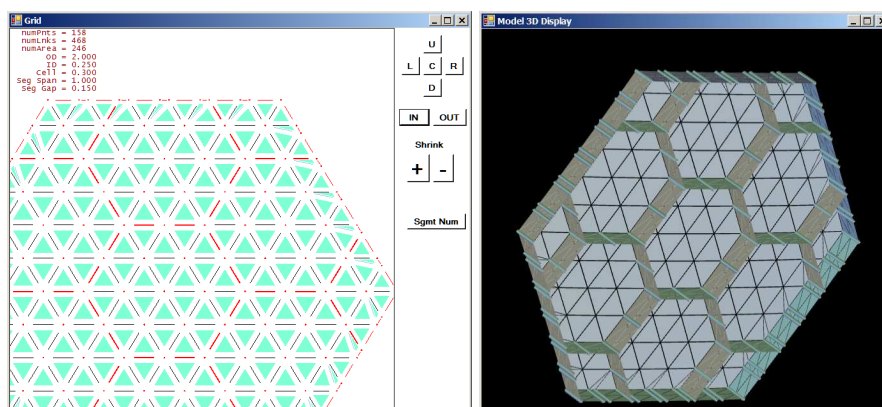
Outer Dia	2	☐ Each Segment ☒ Whole Mirror	☒ Show Whole Grid ☐ Show Supports ☐ Show Fillets	DISPLAY GRID
Inner Dia	0.25			DISPLAY MODEL
Cell Width	0.3			WRITE MODEL
Lip Inner	0.05			SAVE RESTORE
Segment Lip	0.05			MERGE NODES
Mirror Lip	0.1			
Num Rings	0	Modal (PSD) Boule Mapping Grid Options Optical Reals Core Hexapod Axial Radial Inertial Loads		
Sgmt Span	1	☐ Outer Sgmt Lip ☐ Outer Mirror Lip ☐ Inner Mirror Lip ☐ Circular Segment ☐ Circular Mirror ☒ Seal Ring Outer ☒ Seal Ring Inner ☒ Seal Ring Mirror ☐ Segment Lip Ribs		
Sgmt Gap	0.15	☐ Isogrid Front ☐ Isogrid Back ☐ Backface Holes ☐ Core Projection ☐ Include Fillets ☐ Off Center Pattern ☐ No Backsheet ☐ Central Hole		
Merge Tol	0.025	☐ Cell Level 0 ☐ Cell Level 1 ☒ Cell Level 2		
Grid Zoom	1			
Segment Shown	1			
Srink Factor	0.05			
Status				



BOTH 2D AND 3D DISPLAYS

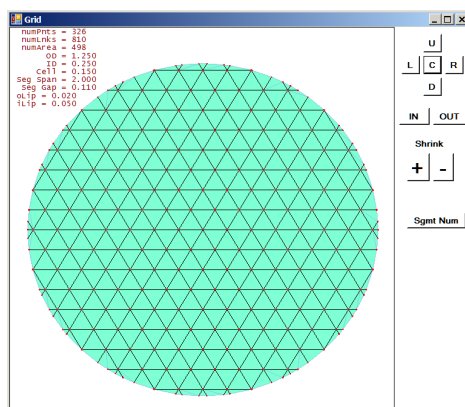


GUI ALLOWS PAN AND ZOOM

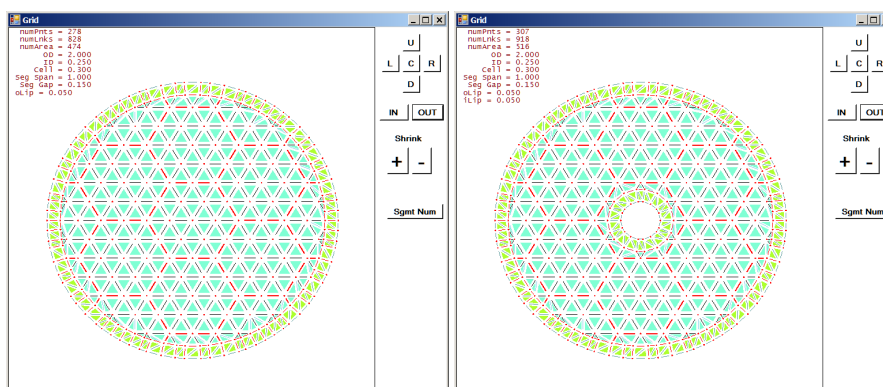




QUICKLY REMESH

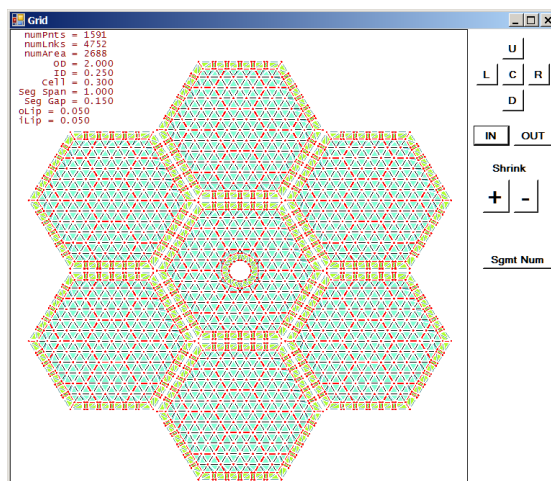


ADD CENTRAL HOLE EASILY

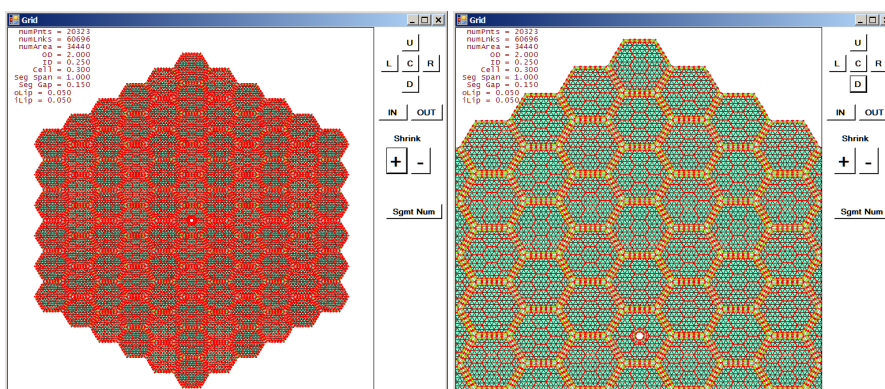




MODEL SEGMENTED MIRRORS

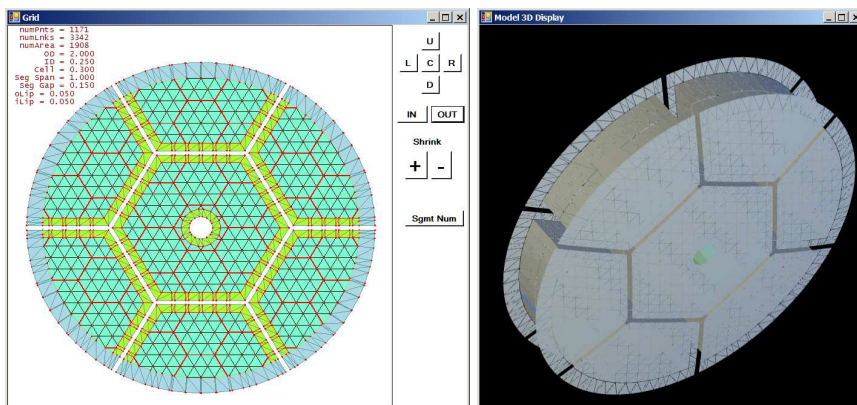


ALMOST UNLIMITED SIZE

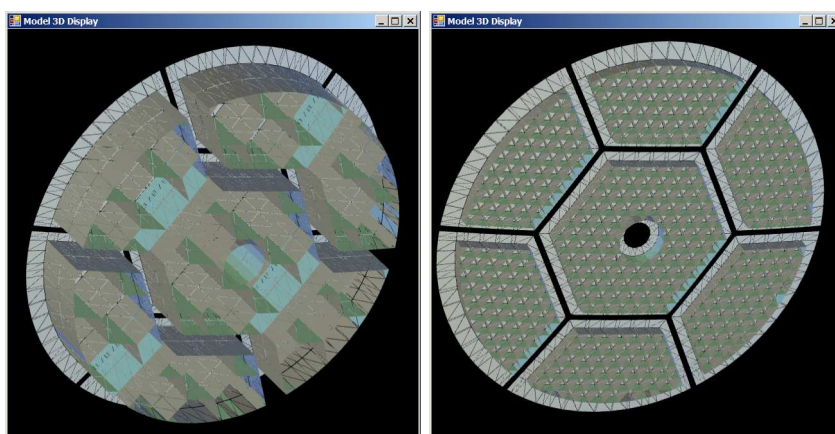




MODEL CIRCULAR SEGMENTED MIRRORS

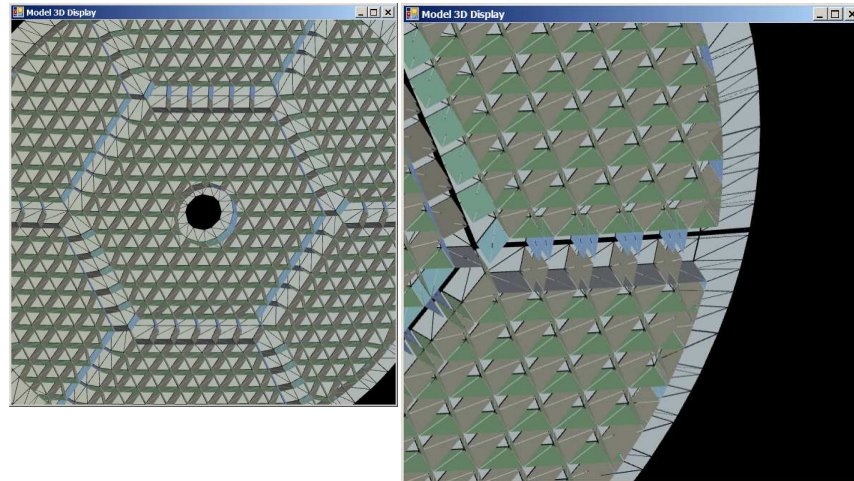


SUPPORTS ISOGRID FACESHEETS

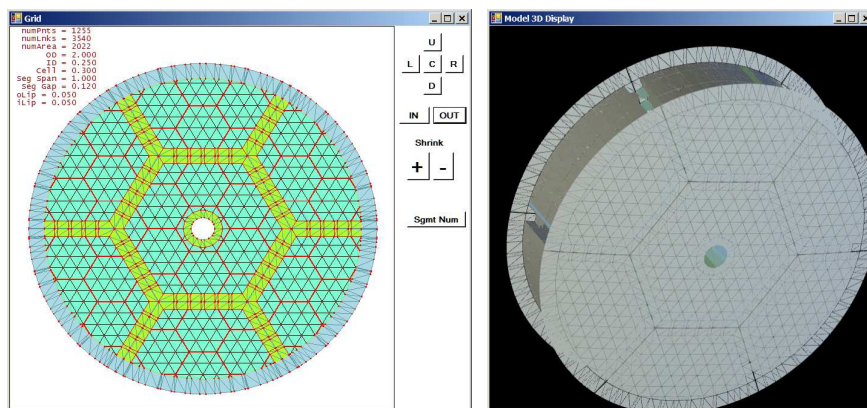




EDGES CAN HAVE RIBS

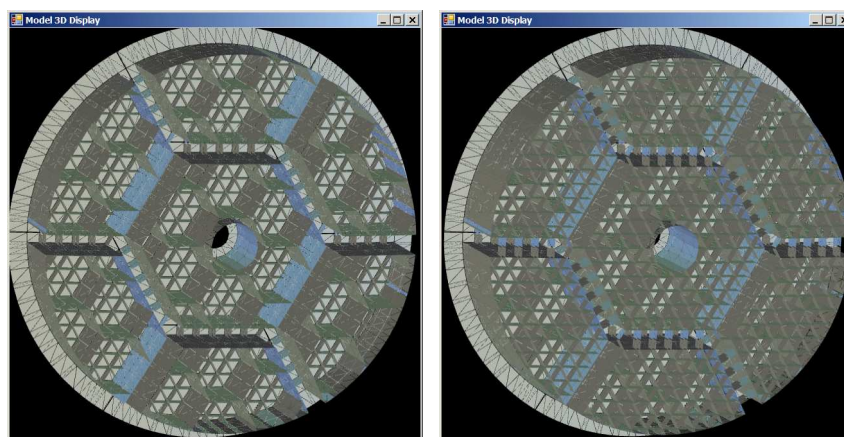


MODEL CAN BE MERGED IN ONE MIRROR

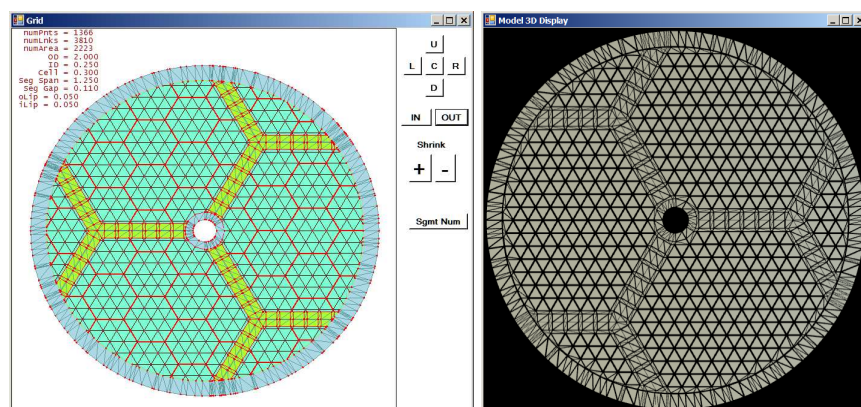




FRONT AND BACK ISOGRIDS SUPPORTED

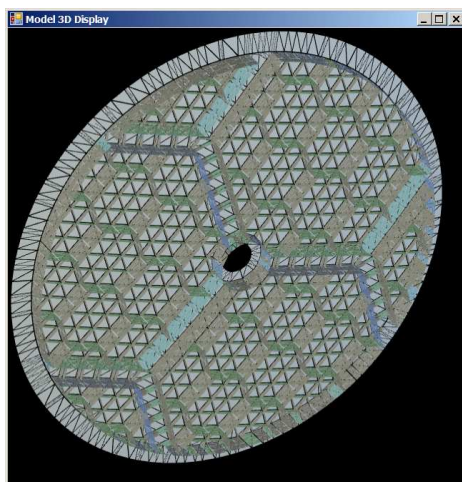


OFFSET SUPER-CELLS SUPPORTED

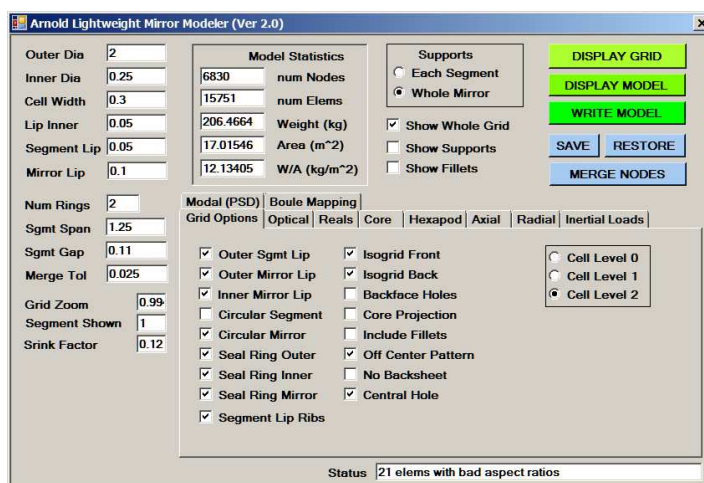




WITH OR WITHOUT SEAL RINGS



MODEL STATISTICS ON THE FLY





ANY OPTIC SUBSCRIPTION SUPPORTED



Arnold Lightweight Mirror Modeler (Ver 2.0)

Outer Dia	2	Model Statistics 6830 num Nodes 15751 num Elems 206.4664 Weight (kg) 17.01546 Area (m ²) 12.13405 W/A (kg/m ²)	Supports ☐ Each Segment ☒ Whole Mirror		DISPLAY GRID
Inner Dia	0.25		☒ Show Whole Grid ☐ Show Supports ☐ Show Fillets	DISPLAY MODEL	
Cell Width	0.3			WRITE MODEL	
Lip Inner	0.05			SAVE	
Segment Lip	0.05			RESTORE	
Mirror Lip	0.1			MERGE NODES	
Num Rings	2	Modal (PSD) Boule Mapping Grid Options: Optical Reals Core Hexapod Axial Radial Inertial Loads			
Sgmt Span	1.25	Radius	7.5	Coefficient(1)	0
Sgmt Gap	0.11	Conic	-1	Coefficient(2)	0
Merge Tol	0.025	Aspheric Order	0	Coefficient(3)	0
Grid Zoom	0.99			Coefficient(4)	0
Segment Shown	1			Coefficient(5)	0
Srink Factor	0.12				

Status 21 elems with bad aspect ratios



CONTROL OVER MOST VARIABLES



Arnold Lightweight Mirror Modeler (Ver 2.0)

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Inner Dia	0.25		☒ Show Whole Grid ☐ Show Supports ☐ Show Fillets	DISPLAY MODEL		
Cell Width	0.3			WRITE MODEL		
Lip Inner	0.05			SAVE		
Segment Lip	0.05			RESTORE		
Mirror Lip	0.1			MERGE NODES		
Num Rings	2	Modal (PSD) Boule Mapping Grid Options: Optical Reals Core Hexapod Axial Radial Inertial Loads				
Sgmt Span	1.25	r, 1	0.005	Front Facesheet	☒ Show	Mirror Material ☒ ULE ☐ Zerodur ☐ E6 ☐ Fused Silica ☐ BK7 ☐ Silicon Carbide
Sgmt Gap	0.11	r, 2	0.005	Back Facesheet	☐ Show	
Merge Tol	0.025	r, 3	0.005	Front IsoGrid Web	☒ Show	
Grid Zoom	0.99	r, 4	0.005	Outer Seal Ring	☒ Show	
Segment Shown	1	r, 5	0.005	Inner Seal Ring	☒ Show	
Srink Factor	0.12	r, 6	0.005	Core Web	☒ Show	
		r, 7	0.005	Back IsoGrid Web	☐ Show	
		r, 8	0.015	Front Outer Seg Lip	☒ Show	
		r, 9	0.015	Back Outer Seg Lip	☐ Show	

Status 21 elems with bad aspect ratios



CONTROL OVER CORE DESIGN



Arnold Lightweight Mirror Modeler (Ver 2.0)

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Inner Dia	0.25			DISPLAY MODEL
Cell Width	0.3			WRITE MODEL
Lip Inner	0.05			SAVE RESTORE
Segment Lip	0.05			MERGE NODES
Mirror Lip	0.1			
Num Rings	2	Modal (PSD) Boule Mapping Grid Options Optical Reals Core Hexapod Axial Radial Inertial Loads		
Sgmt Span	1.25	Front Depth 0.0254 Core Depth 0.0762 Back Depth 0.0254 Total Depth 0.127 Core Layers 2		
Sgmt Gap	0.11	CoreWeb Fillet Radius 0.005 IsoGrid Fillet Radius 0.005		
Merge Tol	0.025			
Grid Zoom	0.99			
Segment Shown	1			
Srink Factor	0.12			
		Status 21 elems with bad aspect ratios		



WHOLE MIRROR OR SEGMENT SUPPORTS

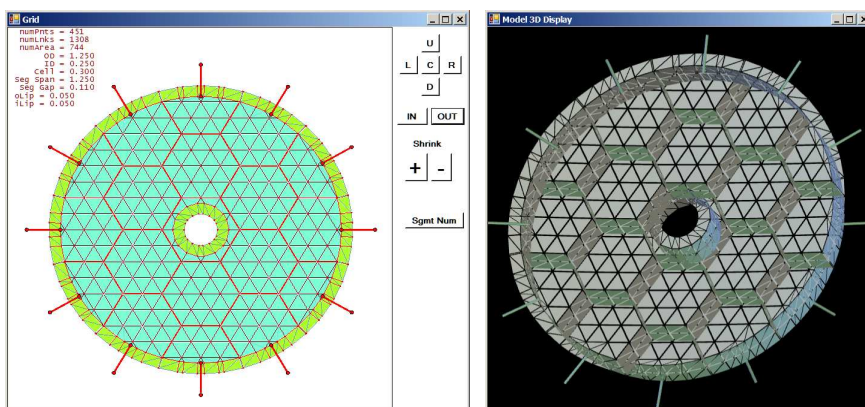


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Inner Dia	0.25			DISPLAY MODEL
Cell Width	0.3			WRITE MODEL
Lip Inner	0.05			SAVE RESTORE
Segment Lip	0.05			MERGE NODES
Mirror Lip	0.1			
Num Rings	2	Modal (PSD) Boule Mapping Grid Options Optical Reals Core Hexapod Axial Radial Inertial Loads		
Sgmt Span	1.25	Num Points 12 Support Length 0.15 (m) Spring Rate 2000 (N/m) Start Angle 0 (deg) Fitting Mass 1 (kg) Acceptable Near 1E-05 (m)		
Sgmt Gap	0.11	☐ Do Radial Support		
Merge Tol	0.025			
Grid Zoom	0.99			
Segment Shown	1			
Srink Factor	0.12			
		Status 21 elems with bad aspect ratios		



USER CAN ADJUST AND OPTIMIZE



AXIAL AS WELL AS RADIAL STYLES



Arnold Lightweight Mirror Modeler (Ver 2.0)

Outer Dia: 1.25
 Inner Dia: 0.25
 Cell Width: 0.3
 Lip Inner: 0.05
 Segment Lip: 0.05
 Mirror Lip: 0.1

Num Rings: 0
 Sgmt Span: 1.25
 Sgmt Gap: 0.11
 Merge Tol: 0.025

Grid Zoom: 0.99
 Segment Shown: 1
 Shrink Factor: 0.12

Supports:
☐ Each Segment
☒ Whole Mirror

☒ Show Whole Grid
☒ Show Supports
☐ Show Fillets

Modal (PSD) | Boule Mapping
 Grid Options | Optical | Reals | Core | Hexapod | Axial | Radial | Inertial Loads

Pnts	Diameter (m)	Start Ang (deg)	Spring Rate (N/m)
12	0.85	15	2000
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

☒ Do Axial Support

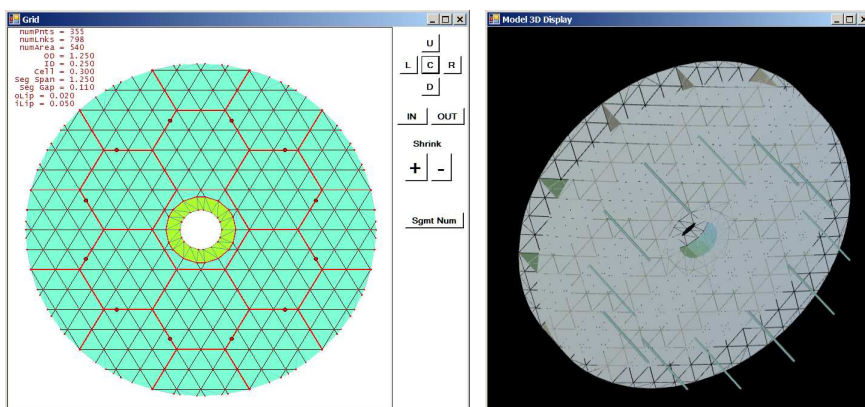
Fitting Mass: 1 (kg)
 Support Ground: 0.5 (m)
 Acceptable Near: 1E-05 (m)

Buttons: DISPLAY GRID, DISPLAY MODEL, WRITE MODEL, SAVE, RESTORE, MERGE NODES

Status: Finished Building Grid



MODEL TEST MOUNTS, ETC



ANY VARIETY OF HEXAPOD SUPPORT



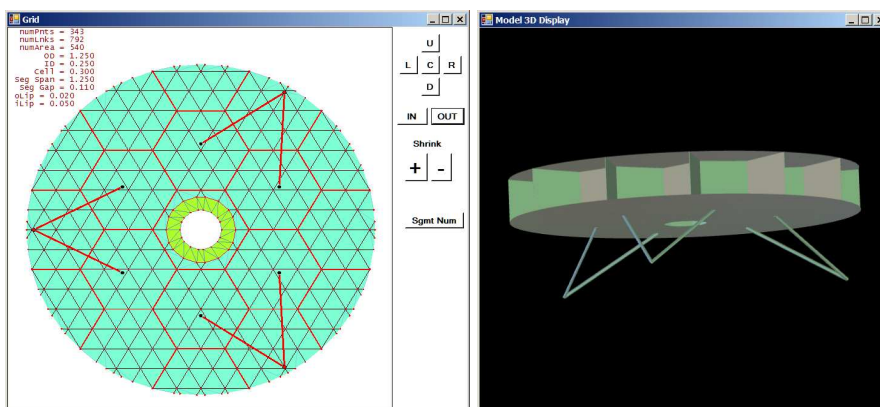
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Inner Dia	0.25		☒ Show Whole Grid	DISPLAY MODEL	
Cell Width	0.3		☐ Show Supports	WRITE MODEL	
Lip Inner	0.05		☐ Show Fillets	SAVE RESTORE	
Segment Lip	0.05		MERGE NODES		
Mirror Lip	0.1				
Num Rings	2	Modal (PSD) Boule Mapping Grid Options Optical Reals Core Hexapod Axial Radial Inertial Loads			
Sgmt Span	1.25	☐ Do Hexapod			
Sgmt Gap	0.11	Upper Diameter 1.2 (m) Lower Diameter 1.6 (m) Height (ground) 0.5 (m) Start Angle 0 (deg) Upper Spread 30 (deg) Lower Spread 5 (deg) Acceptable Near 1E-05 (m)			
Merge Tol	0.025	Spring Rate 200000 (N/m) Fitting Mass 1 (kg)			
Grid Zoom	0.99				
Segment Shown	1				
Srink Factor	0.12				

Status 21 elems with bad aspect ratios



WHOLE MIRROR OR EACH SEGMENT



GENERATE STATIC LOADING CONDITIONS

Arnold Lightweight Mirror Modeler (Ver 2.0)

Outer Dia	2	Model Statistics 6830 num Nodes 15751 num Elems 206.4664 Weight (kg) 17.01546 Area (m ²) 12.13405 W/A (kg/m ²)	Supports ☐ Each Segment ☒ Whole Mirror		DISPLAY GRID																																				
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Sgmt Span	1.25	<table border="1"> <thead> <tr> <th></th> <th>Accel X</th> <th>Accel Y</th> <th>Accel Z</th> </tr> </thead> <tbody> <tr><td>1</td><td>0</td><td>0</td><td>0</td></tr> <tr><td>2</td><td>0</td><td>0</td><td>0</td></tr> <tr><td>3</td><td>0</td><td>0</td><td>0</td></tr> <tr><td>4</td><td>0</td><td>0</td><td>0</td></tr> <tr><td>5</td><td>0</td><td>0</td><td>0</td></tr> <tr><td>6</td><td>0</td><td>0</td><td>0</td></tr> <tr><td>7</td><td>0</td><td>0</td><td>0</td></tr> <tr><td>8</td><td>0</td><td>0</td><td>0</td></tr> </tbody> </table>					Accel X	Accel Y	Accel Z	1	0	0	0	2	0	0	0	3	0	0	0	4	0	0	0	5	0	0	0	6	0	0	0	7	0	0	0	8	0	0	0
	Accel X	Accel Y	Accel Z																																						
1	0	0	0																																						
2	0	0	0																																						
3	0	0	0																																						
4	0	0	0																																						
5	0	0	0																																						
6	0	0	0																																						
7	0	0	0																																						
8	0	0	0																																						
Sgmt Gap	0.11	☐ Calculate Static LCs num Loadcases 0																																							
Merge Tol	0.025																																								
Grid Zoom	0.99																																								
Segment Shown	1																																								
Srink Factor	0.12																																								

Status 21 elems with bad aspect ratios



GENERATE DYNAMIC LOADING SETS

Arnold Lightweight Mirror Modeler (Ver 2.0)

Outer Dia	2	Model Statistics 6830 num Nodes 15751 num Elems 206.4664 Weight (kg) 17.01546 Area (m ²) 12.13405 W/A (kg/m ²)	Supports ☐ Each Segment ☒ Whole Mirror		DISPLAY GRID DISPLAY MODEL WRITE MODEL SAVE RESTORE MERGE NODES	
Inner Dia	0.25		☒ Show Whole Grid ☐ Show Supports ☐ Show Fillets	Grid Options Optical Reals Core Hexapod Axial Radial Inertial Loads Modal (PSD) Boule Mapping		
Cell Width	0.3					
Lip Inner	0.05					
Segment Lip	0.05					
Mirror Lip	0.1					
Num Rings	2					
Sgmt Span	1.25					
Sgmt Gap	0.11					
Merge Tol	0.025					
Grid Zoom	0.99					
Segment Shown	1					
Srink Factor	0.12					

Calculate Modes
 num Modes 10

	f1	f2	f3	f4	f5	f6	f7
f	0	0	0	0	0	0	0
g2	0	0	0	0	0	0	0
f	0	0	0	0	0	0	0
g2	0	0	0	0	0	0	0
f	0	0	0	0	0	0	0
g2	0	0	0	0	0	0	0

Calculate X PSD
 Calculate Y PSD
 Calculate Z PSD

Status 21 elems with bad aspect ratios



(IN WORK) ULE CTE MAPPING

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Inner Dia	0.25		☒ Show Whole Grid ☐ Show Supports ☐ Show Fillets	Grid Options Optical Reals Core Hexapod Axial Radial Inertial Loads Modal (PSD) Boule Mapping		
Cell Width	0.3					
Lip Inner	0.05					
Segment Lip	0.05					
Mirror Lip	0.1					
Num Rings	2					
Sgmt Span	1.25					
Sgmt Gap	0.11					
Merge Tol	0.025					
Grid Zoom	0.99					
Segment Shown	1					
Srink Factor	0.12					

Input Boule Data
 Write Boule Data
 Load Boule Data
 List Boule Data

Input Boule Assign Data
 Write Boule AssignData
 Load Boule AssignData
 Map Boules to Model

Status 21 elems with bad aspect ratios



FUTURE ENHANCEMENTS



- **FINISH CTE MAPPING**
- **LOCALIZED MESH REFINEMENT AT ATTACHMENT POINTS**
- **REAL CONSTANT BASED COLOR 3D DISPLAY OF MODEL**
- **AUTOMATIC BAD ASPECT RATIO ELEMENT FLAGGING/PLOTTING**
- **HEXAPOD GEOMETRY OPTIMIZATION**
- **EXPAND ANSYS GENERATED DATA SUMMARIES**
- **ABACUS OUTPUT FORMAT (LOW PRIORITY FOR NOW)**
- **NASTRAN OUTPUT FORMAT (NEEDS SPONSOR)**

- **USER MANUAL**
- **TUTORIAL(S) ON HOW TO USE MODELER**
- **SHORT COURSE IN ADVANCED MIRROR DESIGN METHODS**

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35